Accelerating the next technology revolution

EUV Resist Outgas Testing at SEMATECH-CNSE

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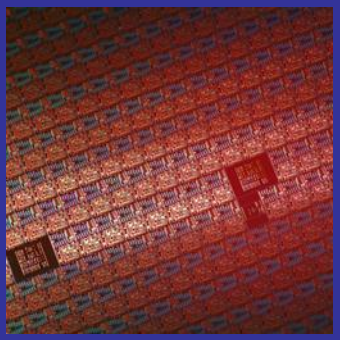


Introduction

- ROX-CNSE-SEMATECH Outgas Testing Tool
  - Hybrid tool (EUV for wafer exposure/E-gun for contamination growth)
  - Certified by ASML
- Relatively high output
  - 3 customer samples a week with 12/7 days coverage
  - Expected to ramp up to 5-7 wafers with 24/7 coverage
- Customer samples
  - Have been processing customer resist samples since April, 2012.

EUV HVM Enablement

- Material outgas testing is a key gap inhibiting implementation of EUV resist materials
  - Shortage of commercially available tools
  - Throughput of available tools is too low
  - Commercial material suppliers typically test a significant number of samples in an effort to optimize formulations
  - Estimated need for testing >1000 samples per year at SEMATECH

- SEMATECH needs to enable their members by providing access to a high volume outgas tool that is certified by ASML

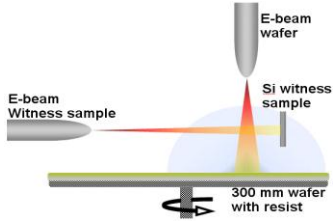
Optics contamination by resist outgassing

- Deposition of contaminations reduces the reflectivity of the EUV optics:
- Two types of contamination:
  - Cleanable: mainly carbon
  - Non Cleanable:
- Cleanable contamination is given as the carbon buildup on a “lens” and can be removed with H* cleaning
  - approx. 1% for 1nm carbon: 6 projection optics: more than10% loss in reflectivity for 2nm carbon
  - Carbon contamination must be kept below 3nm to avoid significant non-recoverable reflectivity loss
  - Non-Cleanable contamination is given as the residue left on the “lens” after cleaning with H*
  - Measurements are given in the atomic % of element traces left in the Ru surface and calibrated to the intensity loss for the given elements
  - Atomic percentage of elements is strictly regulated as this directly shortens lens lifetime

Resist Outgassing Qualification Process

1

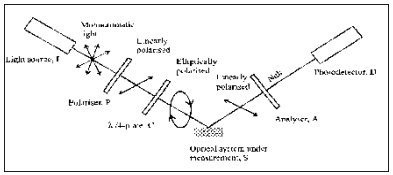
Grow contamination



Tester

2

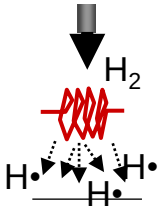
Measure contamination film thickness



Ellipsometry

3

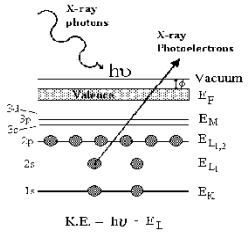
Clean contamination



H* Filament

4

Measure non-cleaned contamination



XPS

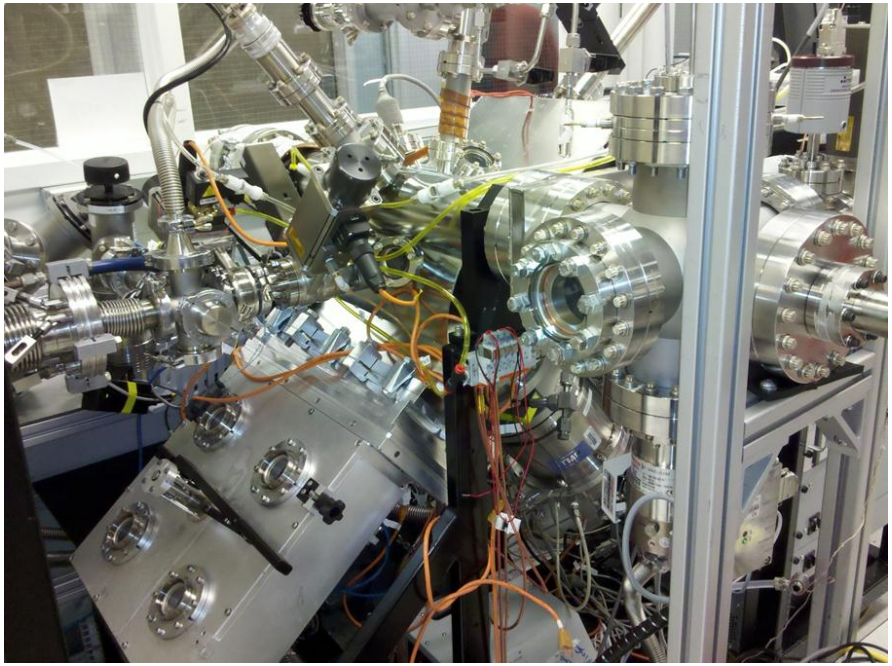
- Ellipsometry measurements allow qualification of *cleanable contamination*

- XPS measurements allow qualification of *uncleanable contamination*
- Uncleanable contamination is the biggest concern for optics lifetime

Facilities

- Coating
  - Wafers processed by SEMATECH on a TEL Clean Track Act 12
- Exposure
  - Custom ROX system at CNSE
    - Energetiq EQ-10M EUV source (wafer exposure)
    - LK Technology EG3000 electron gun (witness plate exposure)
    - 300 mm wafer loadlock
    - Zr filter to block out of band radiation from xenon source
- Post exposure bake
  - 300mm WENESCO hotplate.
- Thickness measurement
  - Woollam M2000 Ellipsometer
- Cleaning
  - Custom tool for cleaning process
- XPS
  - Physical Electronics (PHI) Quantera
- Separate Hydrogen Cleaning Chamber: being built

Testing Facility



CNSE ROX outgas testing tool

EUVT high volume outgas testing tool (being installed)

Dedicated Metrology setup

- SEMATECH has purchased two new metrology tools: faster turnaround time.

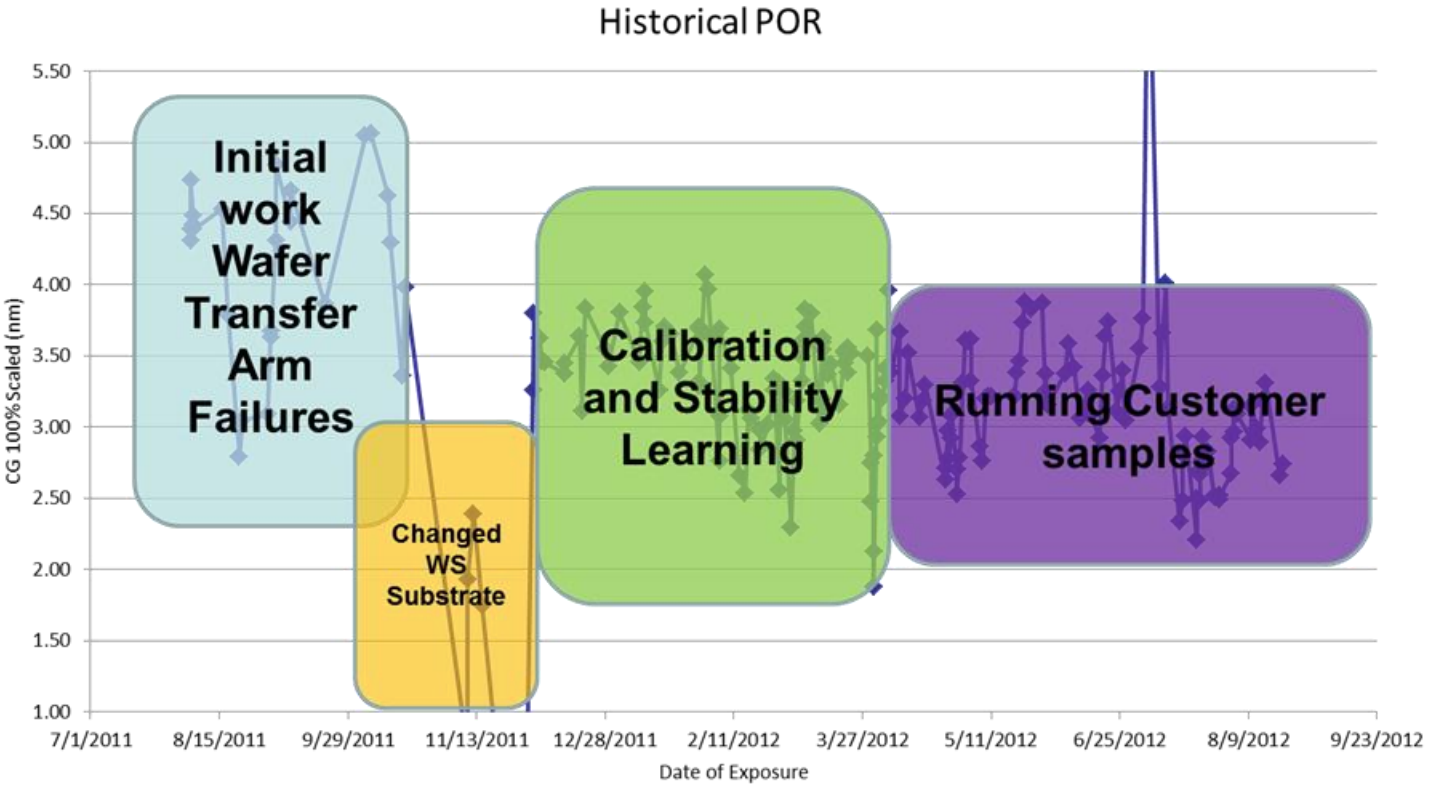
- SEMATECH XPS tool:
  - Tool installed. Passed safety test
  - Tool qualified for use by ASML

- SEMATECH Ellipsometer: Woollam M2000
  - Tool installed and calibration done
  - Tool qualified for use by ASML
  - All thickness measurements have migrated from CNSE tool to this tool.

Process Optimization

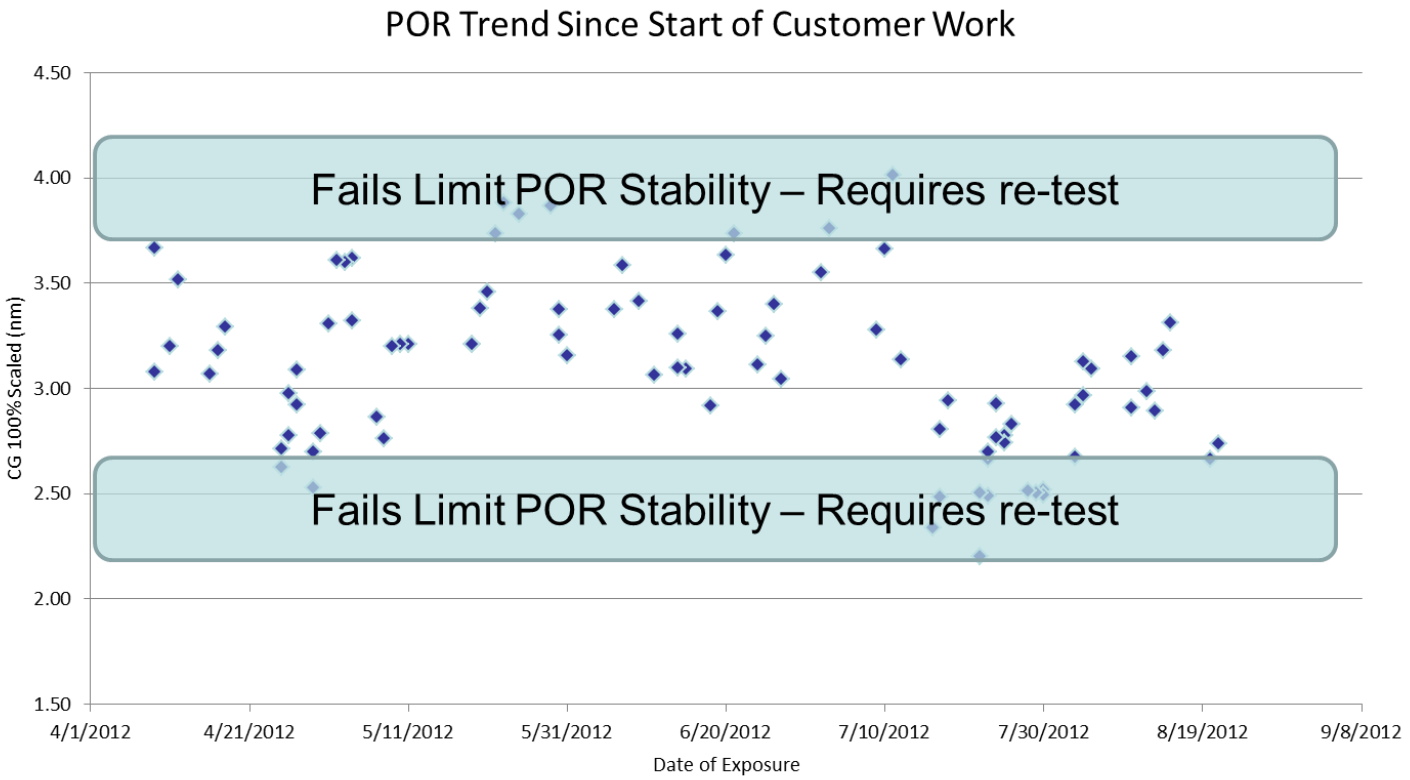
- **RoX tool was originally designed primarily as a research tool**
  - With extensive control in place and daily monitoring, the tool is being converted to work more in a production mode
  - There are still variations in the process: plans being executed separately to develop mitigation strategy: they include
    - Monitoring temperature throughout the tool
    - Monitoring chamber conditioning by RGA
    - Customer exposures are bound between POR exposures
    - Building a separate RGA testing tool to prescreen risky materials to avoid contamination of outgassing system
    - Monitoring the cleaning system cleanliness with XPS and regular plasma cleaning of cleaning system to keep it in spec
    - Upgraded to a pneumatically controlled 300 mm wafer compatible hotplate for E0 testing and monitoring the results of every witness plate exposure wafer by bake and develop for uniformity
    - Procuring spares of the wafer translation and rotation stage system since at this usage rate the lifetime before requiring refurbishment is a few months

POR Historical Work



- Short term stability is good; customer samples done within that period.
- Challenges with long term stability: Schedule optimization/POR run
- Closed loop temp control/stage modification work ongoing

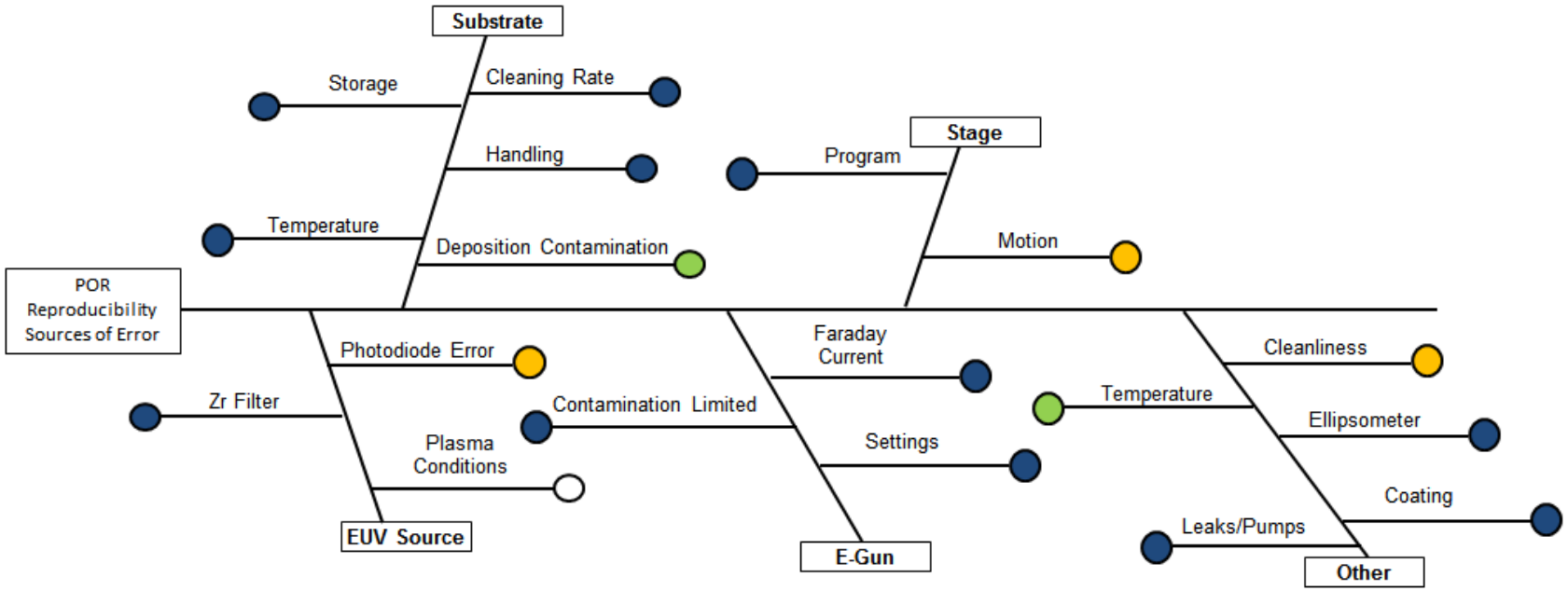
POR Stability Monitor & Control Limits



If, Mean +/- N*sigma < Specs, then proceed with customer sample testing

POR Excursion: Failure Analysis

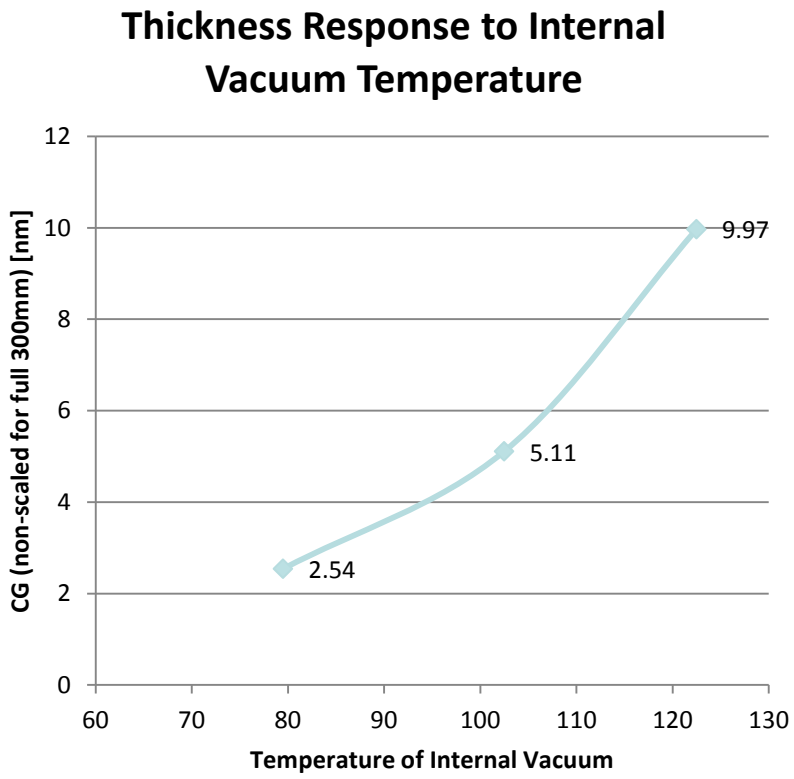
- Fishbone Failure Analysis Tool



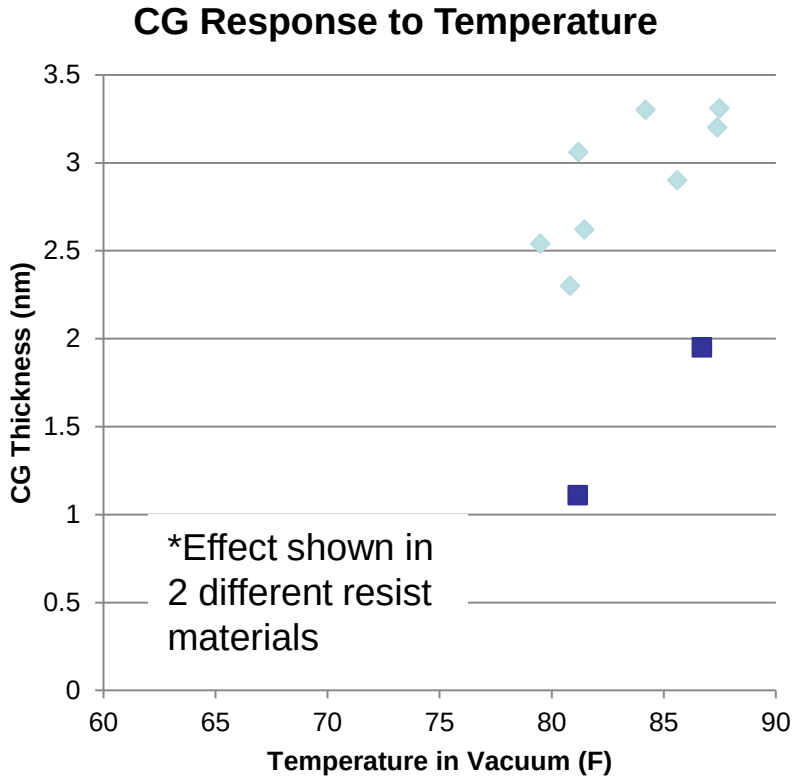
- Actively Controlled
- Actively Monitored
- Found Issues

Vacuum & Lab Temperature Effect on POR

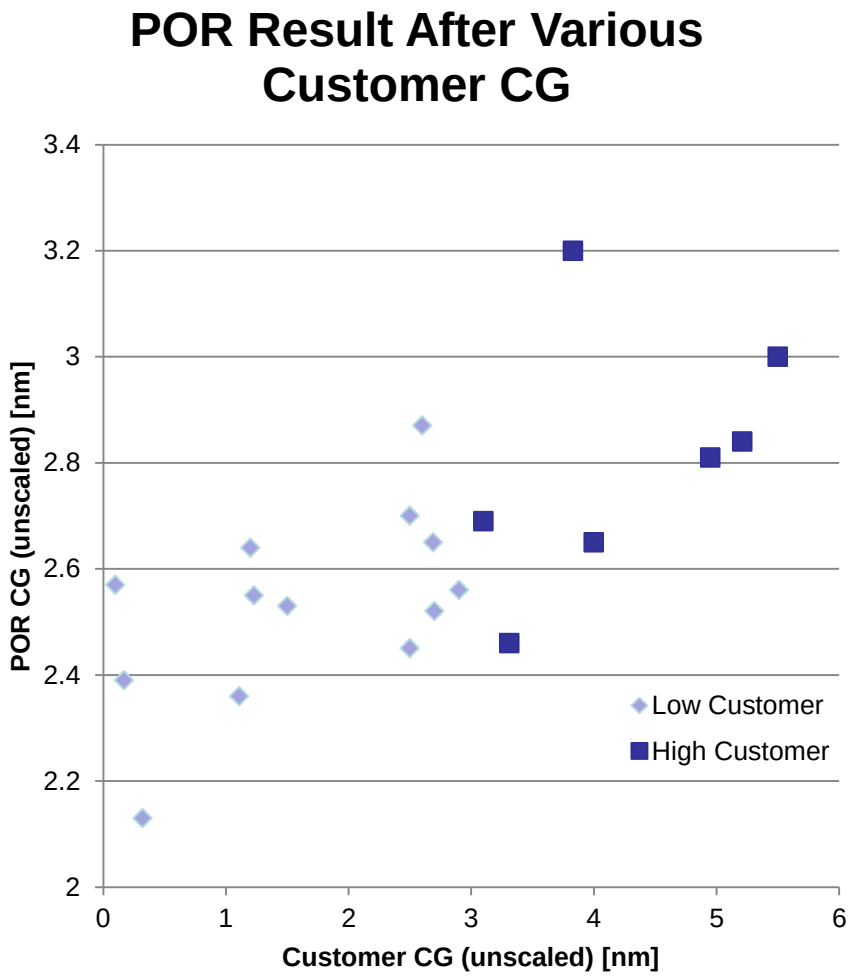
<u>Induced</u> with Bulbs/Heater Tape



Effect From Variations of Lab Temperature (changes the vacuum temp)



Molecular Residence Time from Previous Exposure



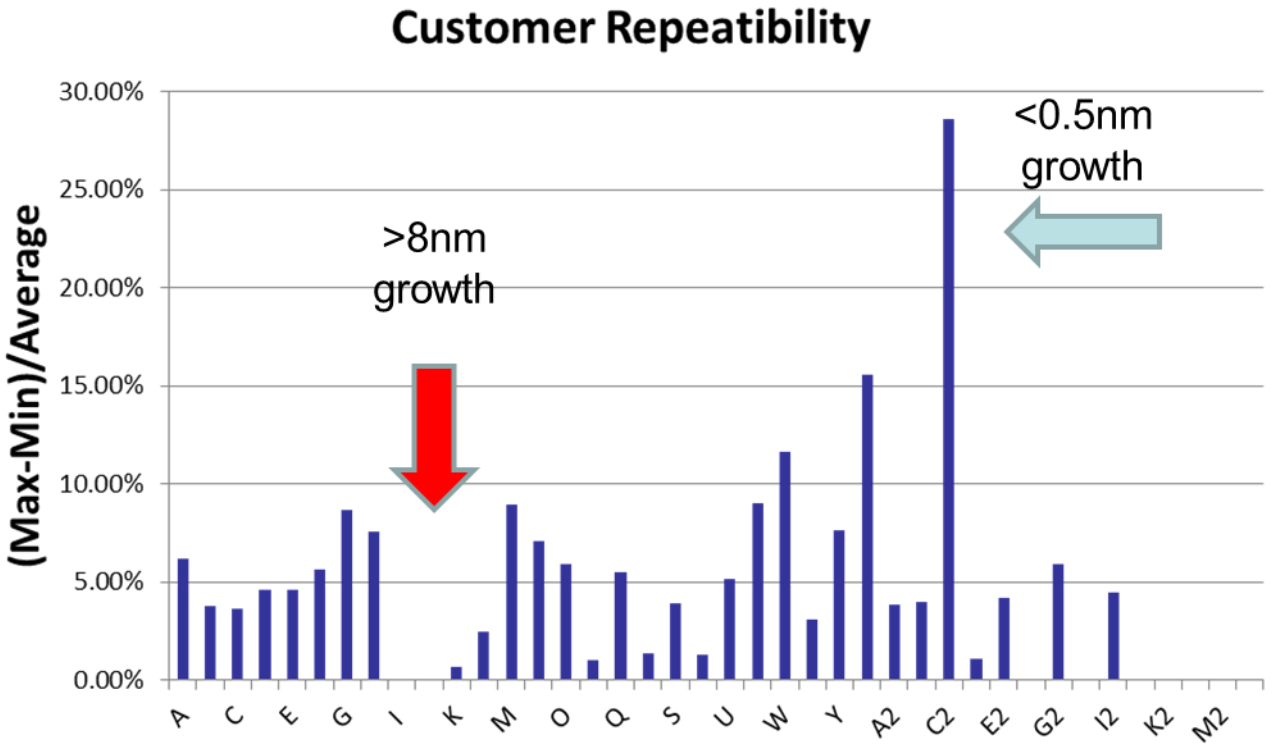
- 3 exposures/day
- Delay 2 hours between
- Residence effect still present
  - Controlled with exposure schedule

	Before Customer	After Customer
Average CG (nm)	2.54nm	2.77nm

POR Stability Mitigation: Controlled with Scheduling

- Temperature Monitor regularly checked
  - New closed loop temp control system is being implemented
  - Wafer stage with 3point mount- aluminum plate is being designed to minimize thermal contact
- Customer exposures separated by POR to minimize previous exposure effect
- POR Failure results in any customer work scrapped and redone
- Customer results subject to tight reproducibility specification.

Reproducibility Customer Samples



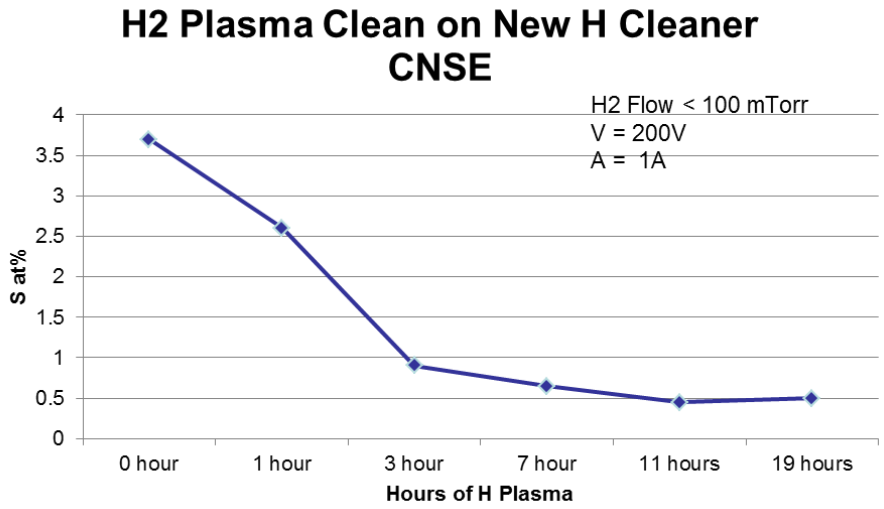
Average reproducibility of customer samples= 6.7%

Lesson learned: S Controlled with H Plasma

- Sulfur initially present in H Cleaning system at levels above ASML specification
- H plasma to reduce S in Cleaner successful
- H plasma allowed all parts to remain present: holder, and HRG filament

*S at% determined from XPS analysis of WS cleaned for equivalent 1nm carbon growth

*Hours in Total



Lessons Learned: S Monitor Before Clean and After Clean

- Storage induced Sulfur:
  - Possible Sources (currently under investigation)
    - Samples stored in vacuum box with resist coated wafers
    - Samples stored in plastic container in vacuum
  - Mitigation Strategy
    - Store in N2 purge in metal container
    - Store in dedicated vacuum box in metal container
      - *Will depend on source of S investigation results*

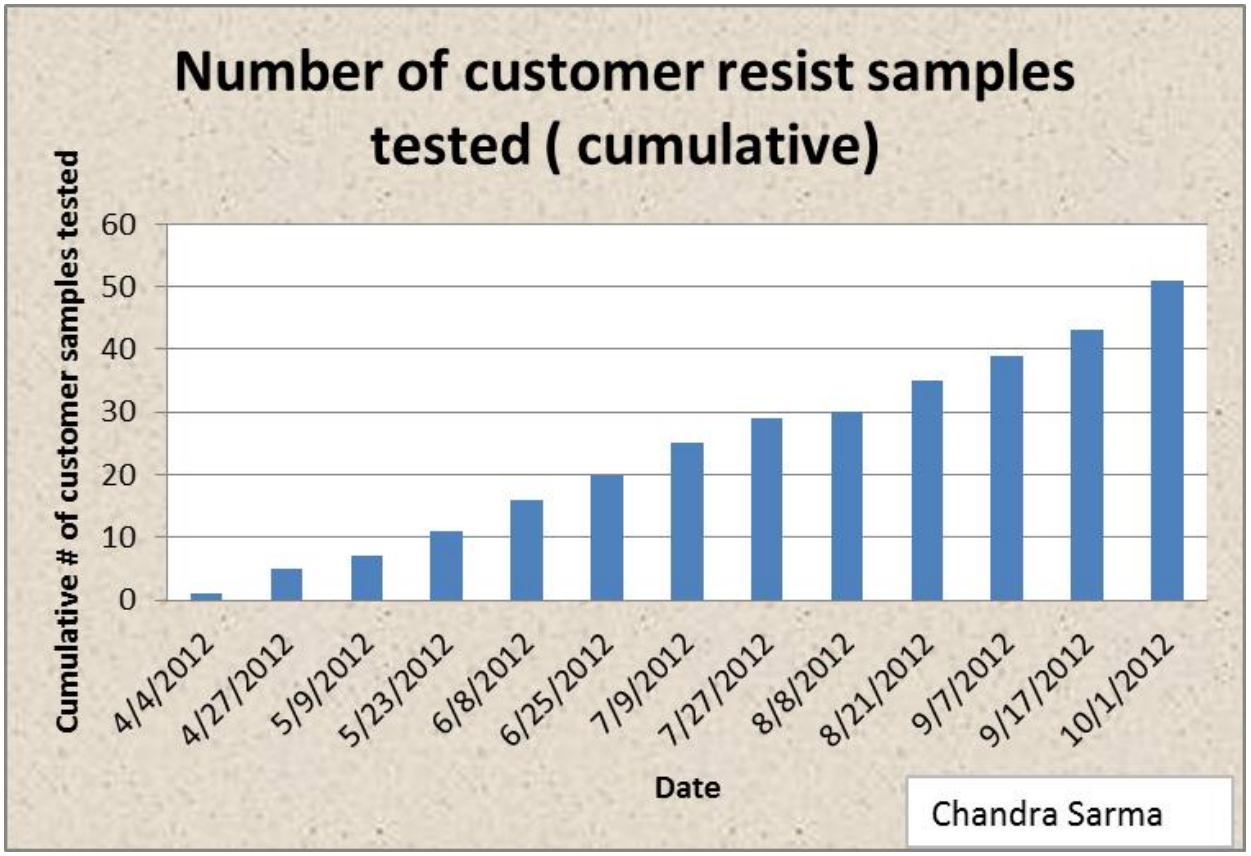
Future Upgrades to the tool

- Throughput enhancement strategy
  - Developing a separate hydrogen cleaning system
  - Upgraded the storage facilities for vacuum storage of wafers and witness plates prior to exposures
  - New dedicated ellipsometer and XPS procured to provide the needed metrology and the faster turn around time for more efficient operation
  - Reduce process variations to enable less number of wafer testing per resist sample

- Upcoming upgrades
  - New RGA capable of real time operation will be added to system for daily monitoring and to reduce the downtime for weekend RGA scans
  - Electron gun will be added for wafer exposures as a back up to the EUV exposures to avoid downtime for EUV source maintenance and provide an alternative to the EUV source to test the effect of source exposure stability on the results
  - Close loop temp control
  - Stage upgrade with three point wafer contact.

Throughput

- Current throughput: 3 resist samples per week plus several POR resist samples for tool monitoring



Ramp up plan

- Current coverage: 12/7
- Ramp up coverage to 24/7: expected throughput of 5-7 samples a week from ROX tool
- EUVT tool is being installed: Major throughput enhancement once the tool is qualified.

Summary

- SEMATECH/CNSE has built a tool that contains a hybrid method of illumination to test resist outgassing.
- To date, this is one of the few ASML-certified tools in the world that is accessible to the entire resist community .
- We have ramped up the tool to test customer samples in a routine manner.
- A high throughput EUVT tool is being installed to meet the resist testing demands.

Acknowledgement

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